Lithostratigraphy and Conodont Biostratigraphy of Fairview and Kope-like Strata in Drill Core 70ZA.

by,
Howard Harper

Introduction

Rocks of the Ordovician age crop out over an extensive area near the intersection of Ohio, Indiana and Kentucky. These rocks are among the most fossiliferous in the world and have been studied for a long time. They have become the American standard for the Upper Ordovician.

This paper deals with the information obtained from a well-preserved core, which in its entirety extends through the Fairview, Kope, Lexington, Tyrone and Camp Nelson formations. This core, drilled by Cominco American Incorporated in July 1970, coded CA-38 by them, designated 70ZA in this paper, allows an exceptional opportunity to add to the knowledge of the Ordovician in its American standard type area. The borehole is located at 38°42'20"N and 83° 54'50"W approximately 1900' northeast of Minerva, Kentucky (Fig.1) on the structural strike of the type section of the Kope Formation.

In this report both the lithostratigraphy of the lower Fairview and the entire Kope Formation and the conodont biostratigraphy of the lower Fairview and upper Kope are discussed. A similar biostratigraphical and lithostratigraphical study of the rocks from the base of the Lexington Limestone up towards the base of the Kope is being done by Dennis Zlatkin. The biostratigraphy from the base of the Lexington Limestone to the lower end of the core is being studied by Robert Votaw. The interval between the upper 187 feet of core and the upper limit of Zlatkin's work has yet to be studied biostratigraphically.

Both lithic identifications and conodont faunal correlations are attempted with other available core and surface section data. The lithostratigraphy is based on the use of shale-percentage logs (Ford, 1967), and the conodont biostratigraphy is based on relative abundance logs (Sweet, Bergström & Rust, 1965). Both procedures have been used successfully in studying similar strata in this area (Ford, 1967; Seddon and Sweet, 1971). The conodont elements procured from the samples are deposited in the micropaleontological collection of The Ohio State University.

I would like to thank Cominco American Incorporated for making the core available for study and the Ohio Geological Survey, who delivered it to The Ohio State University. I would also like to acknowledge the great amount of time and help contributed by Dr. Walter Sweet, The Ohio State University, under whose guidance this project was carried out.

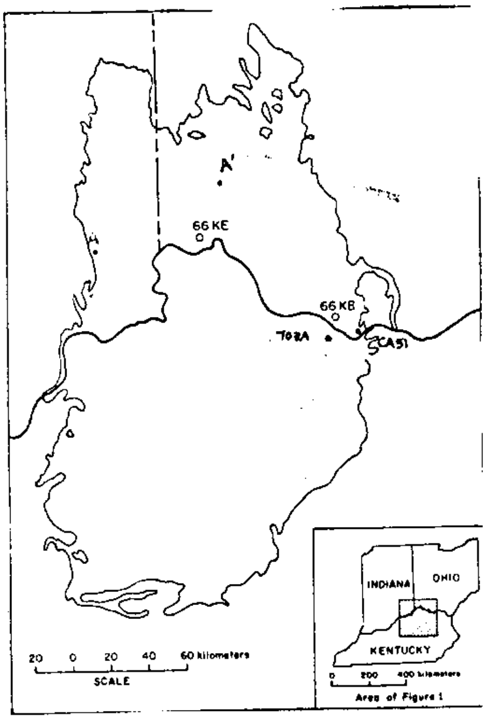


Figure 1: Irregular line indicates the area of Ordovician outcrop in the Cincinnati Region of Ohio, Indiana and Kentucky. Numbers and letters indicate location of sections. (From Sweet&Bergström,1971.)

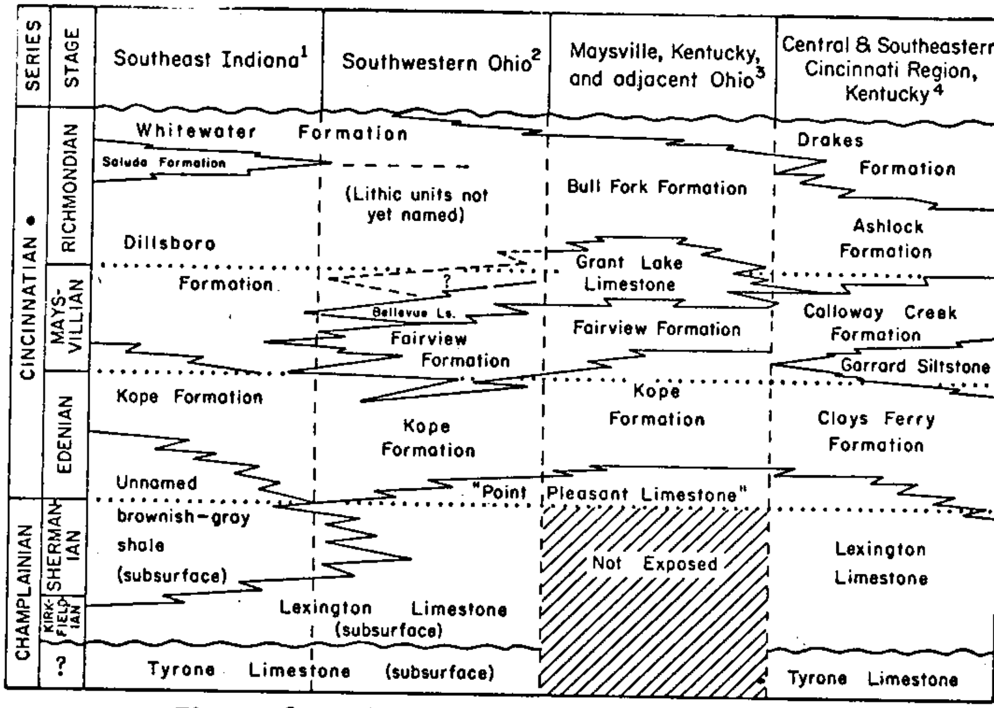


Figure 2: Lithostratigraphic units and approximate relations of Upper Ordovician in the Cincinnati Region. (From Sweet&Bergström 1971

Lithostratigraphy

The general lithic character of the core, which is uniform throughout the section studied, consists of interbedded shale and limestone. The shale is light gray-green and appears massive or poorly laminated. Mineralogical, chemical and textural analysis of Edenian and Maysvillian shale (Scotford, 1965) have shown no significant lateral or vertical variance in the properties of the shale.

Most limestone beds are biogenic and very light gray in color. Some beds are fine grained without large fossil fragments noticeable. An analytical classification of the limestone into seven types, based mostly on size of fossil fragments, amount of insoluble residue, orientation of fossil fragments and lamination, has been done (Weiss & Norman, 1960). Ford (1967) has subdivided some of the types of Weiss and Norman. Although the limestone can be differentiated, the vertical sequence of the different types appears to be in no systematic order that can be analyzed for lithostratigraphic divisions.

Because of the properties of the shale and limestone, lithic divisions within the Upper Ordovician in the Cincinnati Region have developed slowly. A summary of this development was made be Sweet and Bergström (1971) and a more detailed account was given by Weiss and Norman (1960).

The lithostratigraphy, in this paper, is based on shale-percentage logs largely because they have proved successful in lithic identifications (Ford, 1967; Seddon and Sweet, 1971). The method for obtaining data needed for the shale-percentage log consisted of consecutively measuring, identifying as either shale or limestone, and numbering each bed greater than or equal to .01 foot in thickness. The percentage of shale thickness in consecutive three-foot intervals was then calculated and plotted. There was difficulty with missing intervals of the core and one core box was apparently labeled incorrectly for it showed only a one-foot interval for nearly ten feet of core. This was the only major break and is marked on the log. Smaller breaks were averaged into the data with the idea that shales would be the rocks most likely lost from the core. These breaks and others perhaps not discovered allow some flexibility within the log. The author feels that displacements of a few feet along the length of the log are acceptable.

A similar method, but not one used here, involves the use of clastic-ratio logs. The clastic-ratio is found by dividing the thickness of shale and mudstone by the thickness of limstone for a designated interval. (Weiss et al., 1965) It was not chosen because it is more difficult to calculate and the work that has been done with this method uses a moving average, which smoothes finer details of the log and introduces considerable displacement of information along the log. (Weiss et.al.,1965; Weiss & Sweet, 1964). When trying to tie in the conodont relative abundance data, this displacement causes difficulties, for the two types of information are then out of phase.

The logs on page 9 compare shale-percentages from four loaclities.. Log AA' is a composite of two sections. The upper portion is from New Point, Indiana (Fig.1,A) and the lower portion is from Middletown, Ohio (Fig.1,A'). A composite log was necessary because there is a change in lithology below the Kope Formation in southeast Indiana. That is the "unnamed brown-gray shale" (Fig.2). Log B is plotted from data supplied by Mr. A. Janssens from Cominco American Incorporated core CA-51 near Manchester, Ohio (Fig.1). Log C represents the data obtained from core 70ZA.

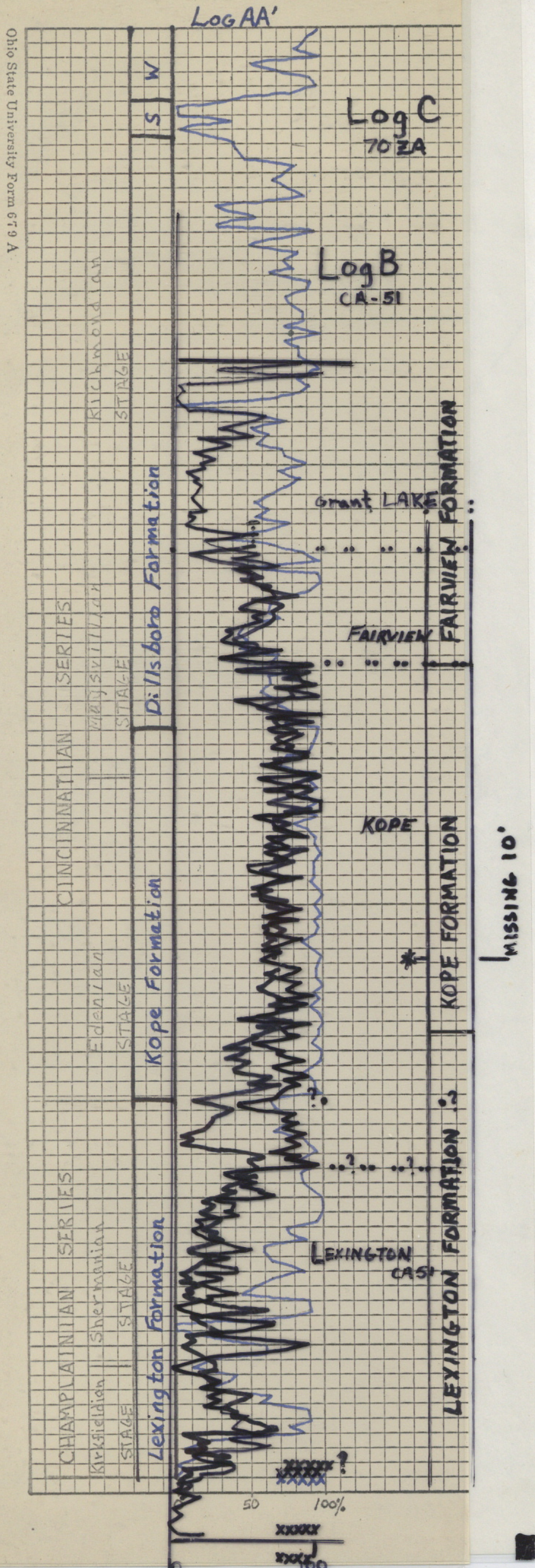
Log C, of 70ZA, begins in the lower Fairview. The Kope-Fairview boundary is defined (Weiss & Sweet, 1964) by putting a clastic-ratio limit of 2.0-∞ on the upper three-fifths of the Kope Formation. This is equal to a shale-percentage of 67% for the lower limit. The Kope-Lexington boundary is similarly defined with a 1.3-11.0 limit of the clastic ratio for the lower limit of 57% on the shale-percentage log. These boundaries are easily distinguished on log C. Ford (1967) redefined the Fairview in its type section (Fig. 1,66KE). He placed the base of the formation at the base of the limestone overlying the uppermost shale bed greater than two feet in thickness. In log C this definition corresponds quite closely with the shale-percentage decrease below the 67% of Weiss and Sweet (1964).

In Kope Hollow, the Kope type section (Fig. 1,66KB) is well exposed only in the lower one-hundred feet. A composite section of Kope Hollow and a section at Maysville, Kentucky (Weiss & Sweet, 1964) yields a total thickness of nearly 260 feet for the Kope. This corresponds very closely to the thickness of the Kope in 70ZA. The *Strophomena planoconvexa* peak zone, that is a few feet below the Kope upper boundary in the Maysville section was not found in the 70ZA core, unfortunately.

Just below the base of the Kope in log C, there is a calcareous unit that probably corresponds to the"Point Pleasant Limestones" (Fig. 2) which lies at the base of the section in Kope Hollow. This unit is absent in both logs AA' and B. A tongue of Kope-like strata only about ten feet thick occurs just below the calcareous unit and just above a definite shift in the shale-percentage and the appearance of the first limestone bed greater than or equal to one foot in thickness.

The three logs, AA', B and C, all tend to support the general concept that deposition during the Upper Ordovician in the Cincinnati Region was on and around the flanks of a somewhat migratory shoal in a shallow sea. The crest and near-crest areas of the shoal are represented by more calcareous deposition, which becomes shalier toward the deeper basin areas. Using the shale-percentage values as a guide log AA', the composite, appears to be the farthest from the shoal crest as most of the log has a higher shale-percentage than log C or B. From its geographic locations (Fig.1) it would be north and west of the crest. Log C seems closest to the shoal-crest because of its lower shale percentage, but southeast of it; and log B suggests that its locality was slightly more to the southeast.

Figure 2, page 3 , expresses the shifting of the shoal-crest through time adequately. In early Eden the crest seemed to be in the Maysville area, lithically characterized by deposition of a calcareous interval, the "Point Pleasant Limestone" or Lexington Limestone. The crest appears to have shifted towards southwestern Ohio by late Edenian with deposition of the Fairview Formation. Through Maysville time, the crest moved back towards the Maysville area with the highly calcareous Grant Lake Limestone suggesting this. This return shows up quite well in log B with the general decrease in shale-percentage from the Fairview upwards.



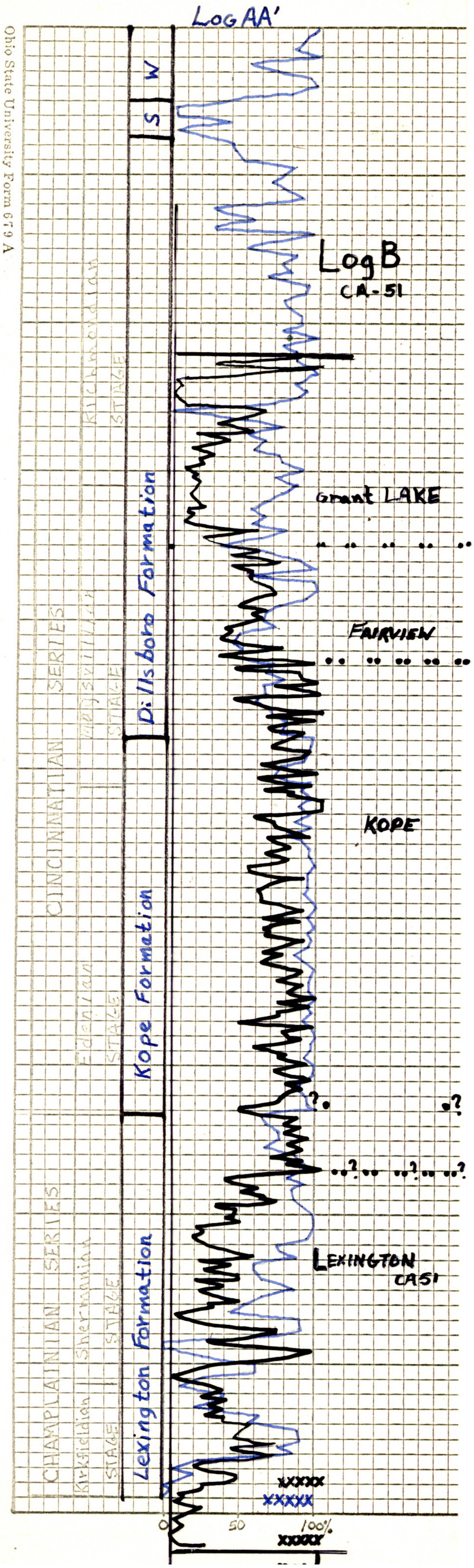
Shale-percentage logs and lithostratigraphic units.

Log AA' = the composite log
S = Saluda Formation
W = Whitewater Formation

Log B = core CA-51
.... = lithic boundary

Log C = core 70ZA

xxx = ash bed (on all logs)



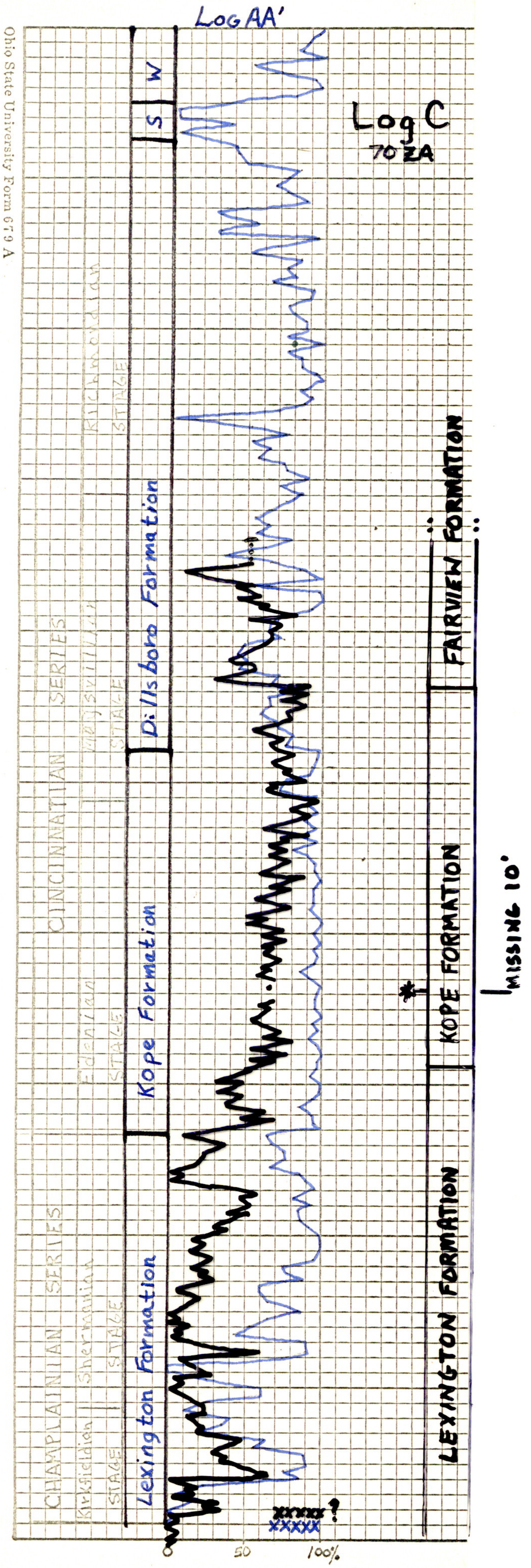
Shale-percentage logs and lithostratigraphic units.

Log AA' = the composite log
S = Saluda Formation
W = Whitewater Formation

Log B = core CA-51
.... = lithic boundary

Log C = core 70ZA

xxx = ash bed (on all logs)



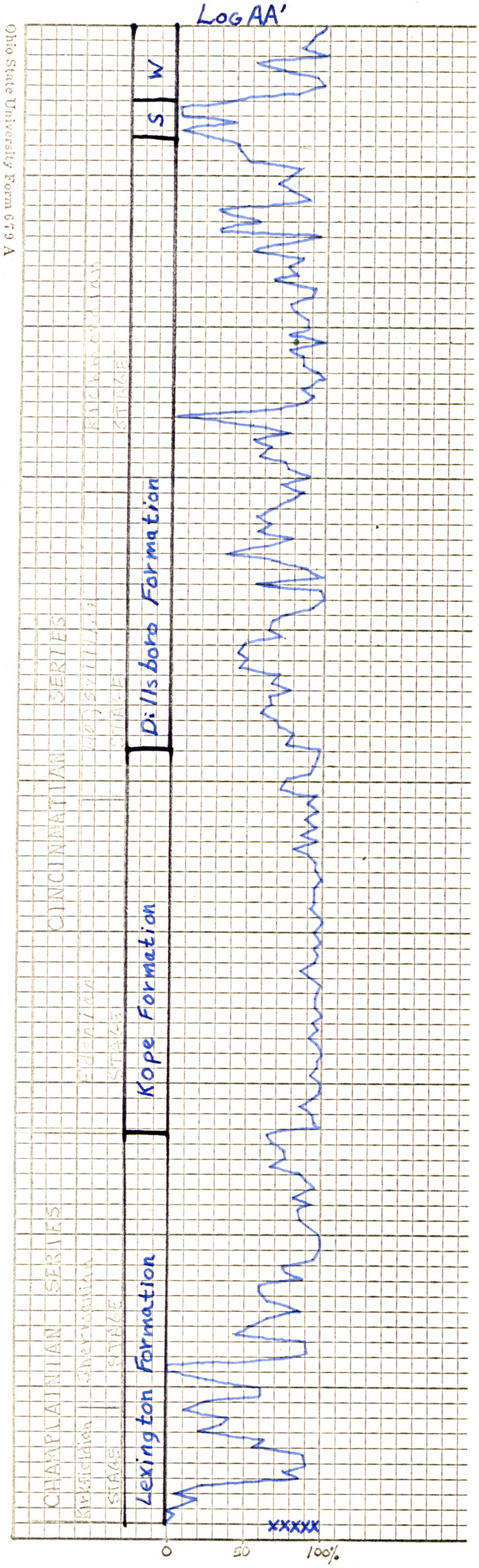
Shale-percentage logs and lithostratigraphic units.

Log AA' = the composite log
S = Saluda Formation
W = Whitewater Formation

Log B = core CA-51
.... = lithic boundary

Log C = core 70ZA

xxx = ash bed (on all logs)



Shale-percentage logs and lithostratigraphic units.

Log AA' = the composite log
S = Saluda Formation
W = Whitewater Formation

Log B = core CA-51
.... = lithic boundary

Log C = core 70ZA

xxx = ash bed (on all logs)

Biostratigraphy

Sampling for conodont elements was done systematically at approximately five-foot intervals. Only limestones were sampled because they have the most abundant assemblage of conodont elements. Because only limestones were sampled, some of the samples were taken at less than a five-foot interval and some at more. The samples, labelled with their footage from the top of the core, were then weighed and up to 520 grams were placed in a 15% glacial acetic acid solution. The acid dissolved the calcium carbonate matrix of the limestone and thus freed the less soluble calcium phosphatic conodont elements. The acid solution had to be changed once for the medium and larger samples, and all samples were adequately reduced within a six or seven day time period. The undissolved residue was then sieved and washed through 16 and 100 mesh screens. All residue greater than 100 mesh was saved; residue greater than 16 mesh was dried, weighed and returned to the sample bag, and residue between 16 and 100 mesh was dried, weighed and further prepared for microscopic study.

Each 16-100 mesh residue was run through a magnetic separator in order to reduce the amount of sample to be studied by separation of ferrous particles in the residue (Dow, 1960). The separator has three variables; amperage, front slope and side slope. Essentially the apparatus works by vibrating the residue down a slope with a forward and side component of inclination.

The non-ferrous particles will move along a vector between the forward and side slopes; the ferrous material, however, will be influenced by the magnectic field and follow a vector much closer to the front slope. A ridge, which begins part way down the inclined slope allows the separated materials to be funneled into individual recepticles. Conodont elements being non-ferrous are in the fraction unaffected by the magnetic field. The amperage and the front and side slopes are different for residues of different sizes and compositions. Settings of 1.5 amperes at 14° front slope and 9° side slope have proved effective for the residues that were studied in this report.

After magnetic separation many residues were still too large to be quickly and effectively studied. Each of these residues was then further fractionated according to the specific gravity of the particles in the residue (Lindström, 1964). A heavy liquid, tetrabromoethane, specific gravity 2.89, was poured into a glass funnel with a short rubber tube and a clamp at the bottom. A single residue was then sprinkled into the tetrabromoethane, stirred with a mixing rod and then allowed to separate. Particles of low specific gravity floated at the surface of the heavy liquid, and heavy particles of specific gravity greater than 2.89 settled towards the bottom of the funnel. Floating material was stirred approximately every 15 minutes and then allowed to settle. This procedure lessened the chances for heavy particles to be rafted by lighter ones. After about one hour, the heavier particles, which have settled well into the tetrabromoethane were drained into filter paper and rinsed thoroughly with acetone to remove all of the tetrabromoethane. Lighter particles were similarly drained into a separate filter paper. Most of the tetrabromoethane was recovered by allowing the acetone to evaporate from the acetone-tetrabromoethane mixture until pure calcite will float in the liquid. Conodont elements with specific gravity 2.84-3.10 settled with the other heavy particles.

Both the heavy particle residues and the very small nonmagnetic residues were then searched for conodont elements. A sample residue was sprinkled on a systematically gridded tray and searched under a microscope. All conodont elements that were found were picked from the tray with a saliva wetted sable hair brush and deposited on a standard sixty square micropaleontological slide. Picked conodont elements were then sorted and identified according to form-species and multielement-spe cies The number of specimens of each form-species comprising a multielement species was then tabulated (Table 1, page 12). The thirty-two samples studied covering the upper 167 feet of the core yielded 4,863 conodont elements of 28 form-species comprising 9 multielement-species and 9 genera.

Conodont biostratigraphy is based on the relative abundance analysis of the Indigenous fauna of the Cincinnatian Region. The Indigenous fauna is comprised of two multielement species:

(Sedden & Sweet, 1971), Phragmodus undatus (Branson and Mehl) and Plectodina furcata (Hinde), which together account for 50 to 90% of each sample.

Phragmodus undatus is composed of four form-elements, and Plectodina furcata of six form-elements. The numbers in Table 1 indicate the sum of all the form-elements belonging to that single multielement species in a given sample. These are the numbers used in the relative abundance logs because as yet no method has been found to identify the number of elements that were actually present in a single organism. Thus the logs represent a combined but inseparable picture of the number of organisms and the number of elements in those organisms.

Data taken from sections 66KE and 66KB (Kohut & Sweet, 1960) ~~was~~ were revised based on the additon of an Ozarkodina and Cyrtoniodus-form elements to the four form-elements which were included in the multielement species Plectodina furcata. Data from 70ZA ~~differs~~ differ from 66KE, 66KB and the composite AA' in that some Trichonodella and Zygognathus -form elements which formerly would be placed with Plectodina furcata , were sorted under Oulodus oregonia as possible form-elements of that species. The author does not believe these differences will affect the analysis of the trends of the logs used for correlation.

Most of the multielement species found in the samples are long ranging Ordovician forms which are of little use in local, short interval correlations. However, by plotting relative abundance logs involving Phragodus undatus and

and Plectodina furcata and matching major trends reasonable correlations have been made within the Cincinnati area. The ecological implications of relative-abundance data are discussed by Seddon and Sweet (1971).

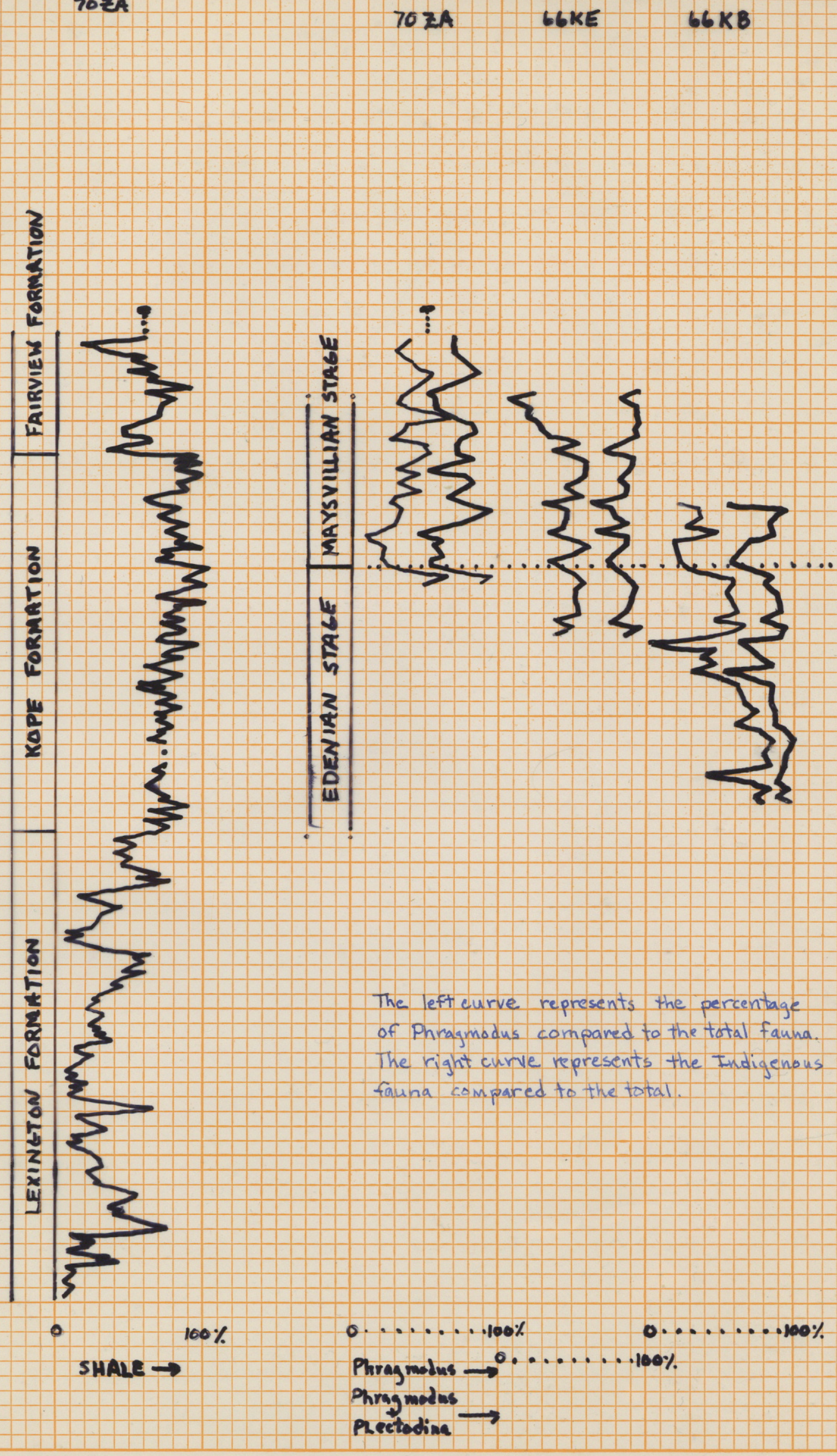
Actually three percentage figures were calculated for each sample. The percentage of Phragmodus undatus of the total number of specimens, the percentage of the Indigenous fauna of the total and the percentage of Phrgmodus undatus of the Indigenous fauna. These were then correlated with other relative abundance logs. Conodont abundance information was available (Kohut & Sweet, 1960) from sampling taken from the Kope type section 66KB and the Fairview type section 66KE - (Fig.1).

The Eden-Maysville time boundary is defined in the Fairview section 66KE and has been correlated, based on the relative aboundance of Phragmodus undatus and the Indigenous fauna against the total number of specimens (Sweet & Bergstrom, 1971). The same information from 70ZA was then correlated with those two sections to determine the Eden-Maysville Boundary within 70ZA (page 16). In Sweet & Bergstrom (1971) the relative abundance logs are used in conjunction with the range of useful species. The interval sampled in 70ZA for this paper is not of great enough length for the ranges of any of the species identified to be useful. Likewise the isolation of the European fauna or the Interior fauna in the percentage logs as in Seddon and Sweet (1971) is of little value in 70ZA because of the scarcity of these species.

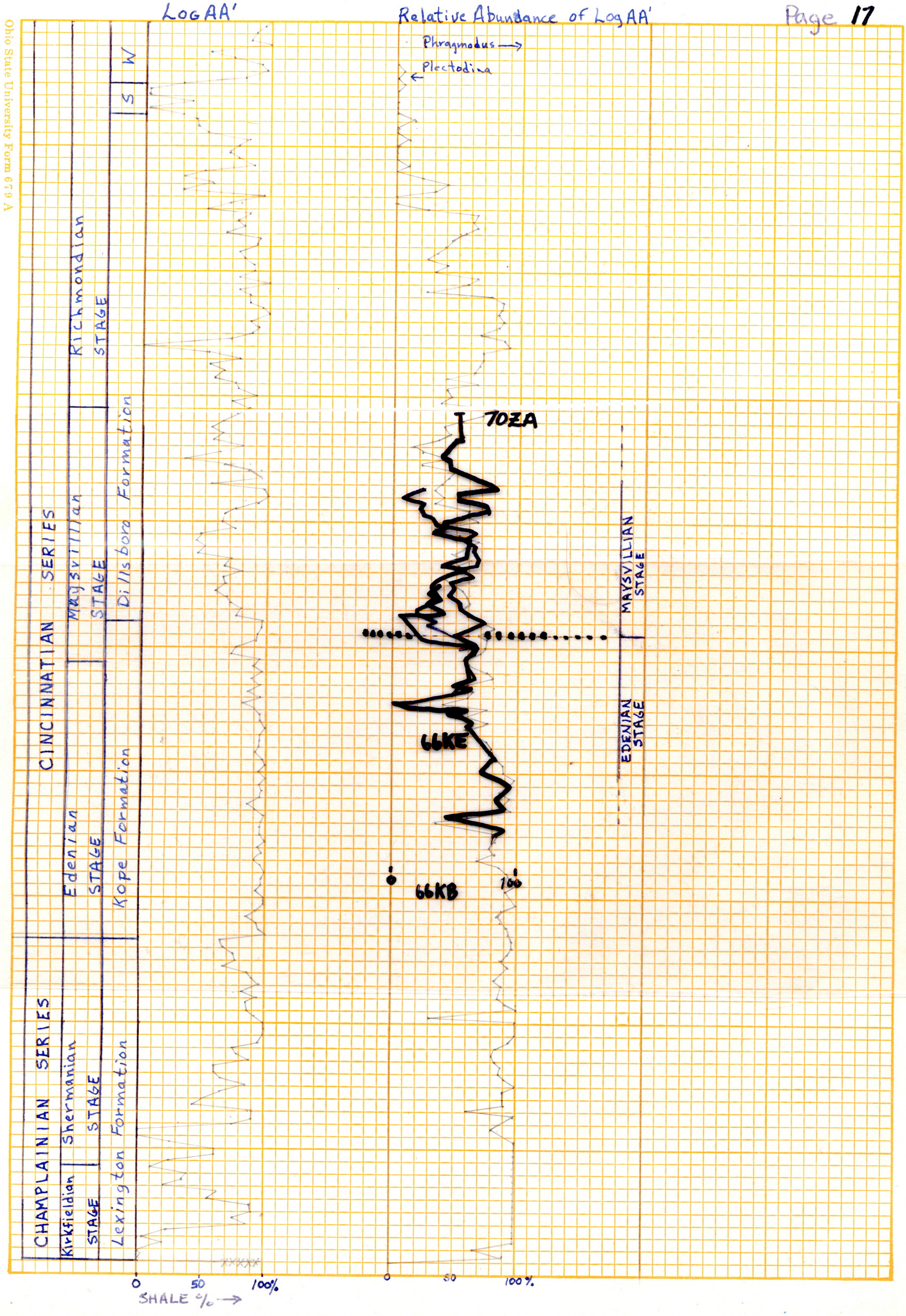
The data from Seddon and Sweet (1971) showing the percentage of Phragmodus Undatus to the indigenous fauna have ~~has~~ proved useful. Similar percentages were calculated from the data of 66KE, 66KB and 70ZA. (page 17). These logs were then correlated with relative abundance log of Log AA'. It is to be noted that major trends in the relative abundance logs are the basis for correlations. Short, drastic changes in the logs are often the effects of the small number of specimens in the sample. Correlation with the relative abundance data of the composite section would indicate that the Eden-Maysville boundary is approximately 20' higher in the composite section than believed.

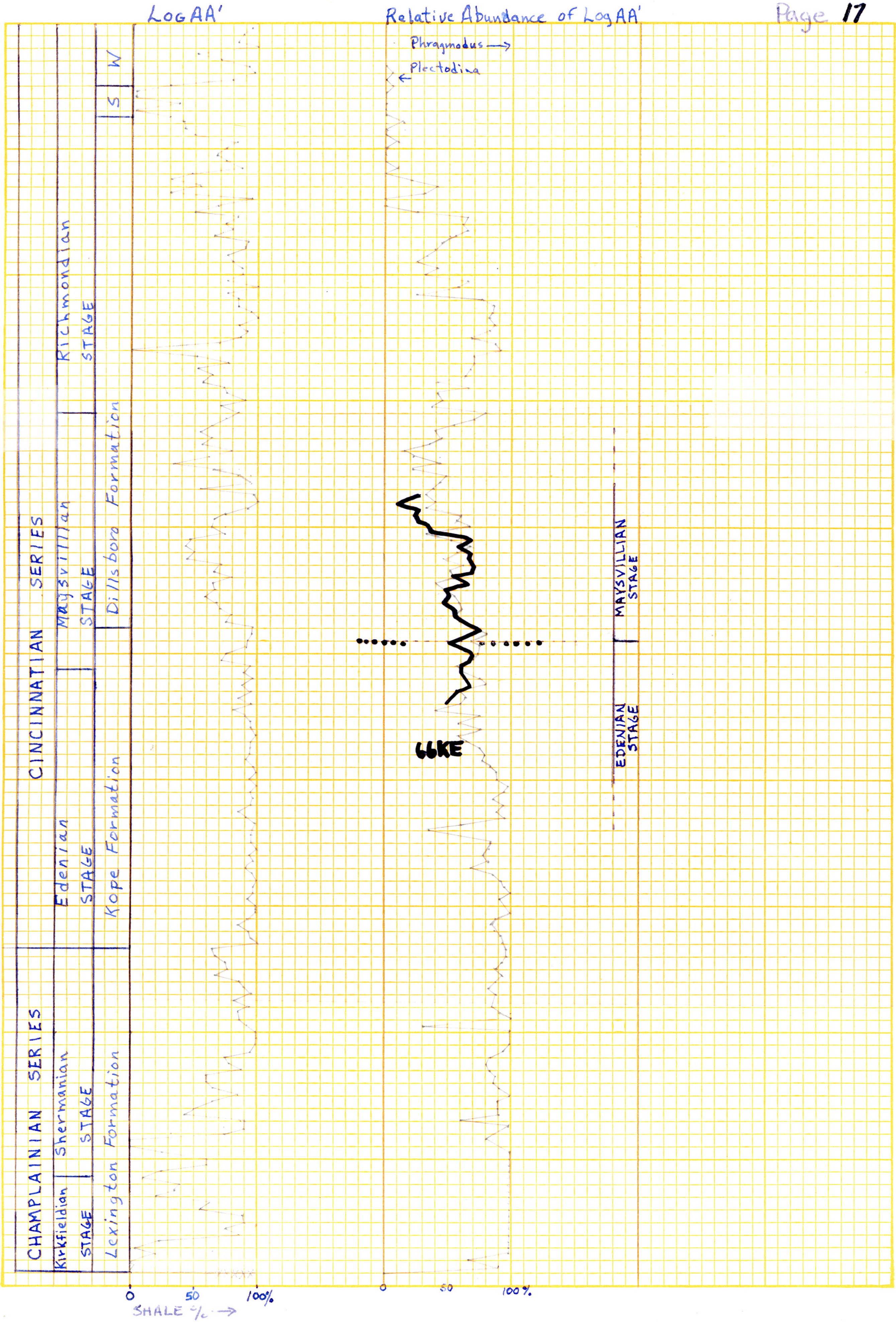
It is hoped that with the addition of the entire biostratigraphic data from 70ZA the time units within the Cincinnati Region will become even better substantiated.

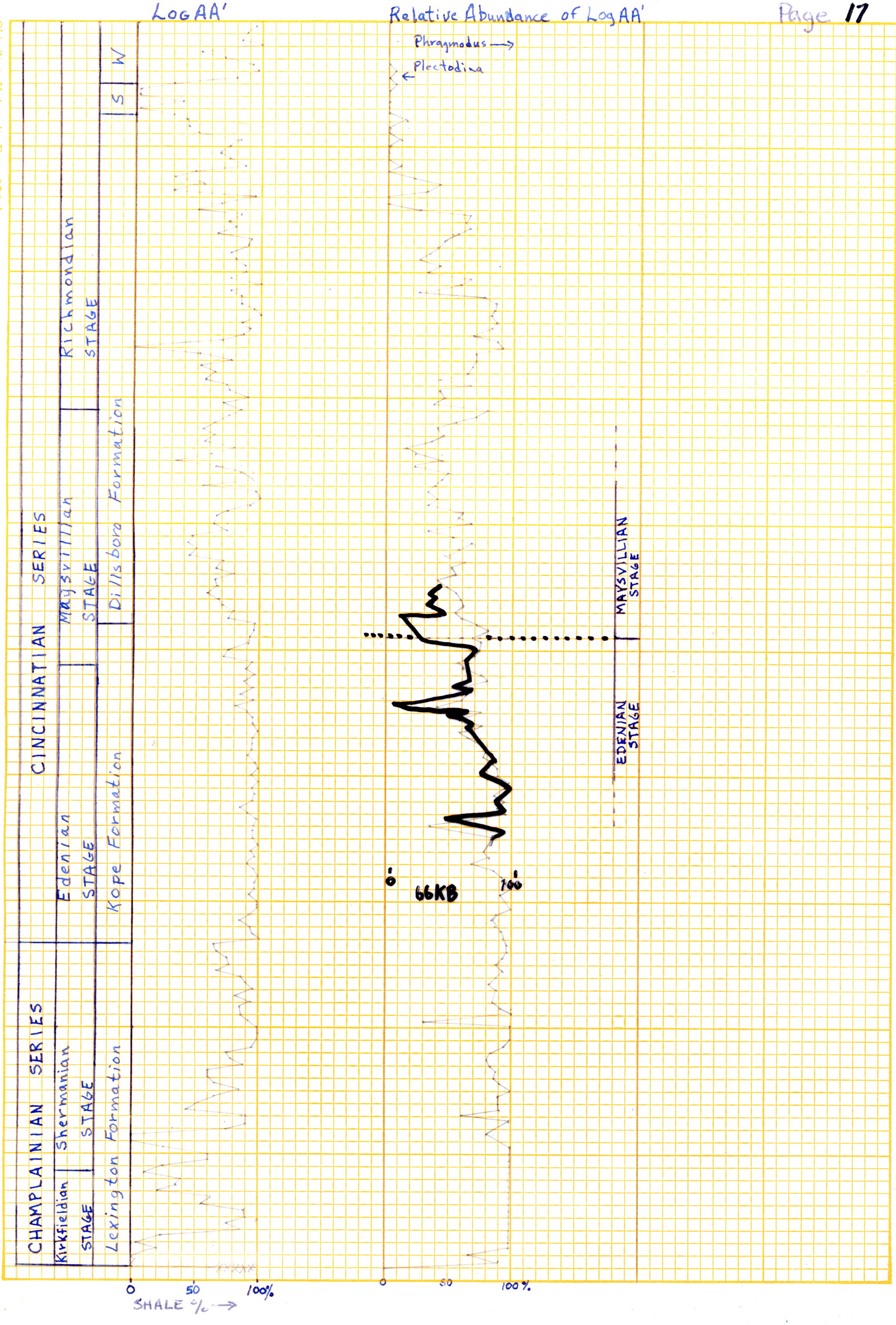
Log C | Relative Abundance



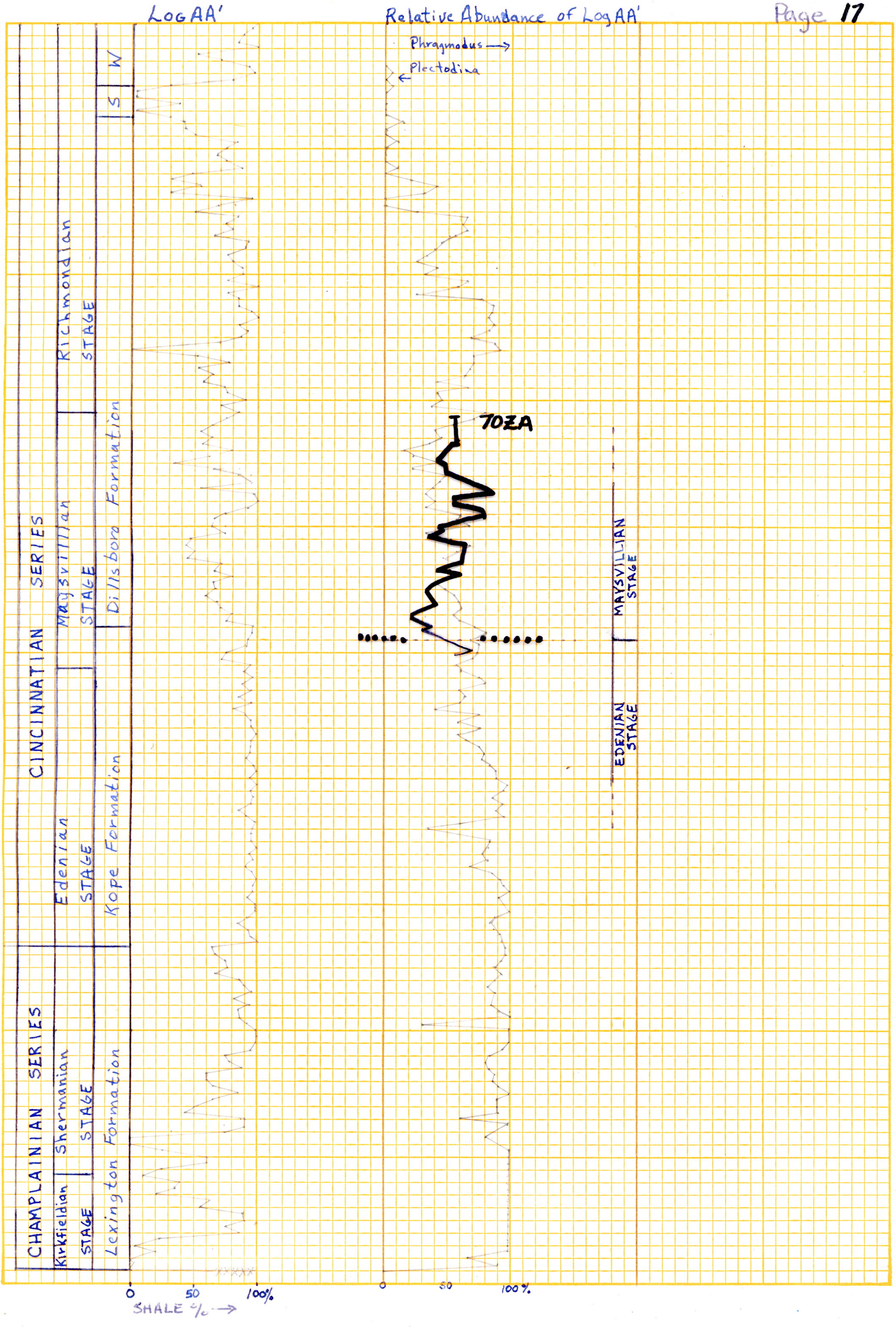
The left curve represents the percentage of Phragmodus compared to the total fauna. The right curve represents the Indigenous fauna compared to the total.


Log AA'
Relative Abundance of Log AA'
Phragmodus →
← Plectodina
CHAMPLAINIAN SERIES
CINCINNATIAN SERIES
Kirkfieldian STAGE
Shermanian STAGE
Edenian STAGE
Maysvillian STAGE
Richmondian STAGE
Lexington Formation
Kope Formation
Dillsboro Formation
S
W
70ZA
66KE
66KB
MAYSVILLIAN STAGE
EDENIAN STAGE
0
50
100%
SHALE % →
Ohio State University Form 679 A


Log AA'
Relative Abundance of Log AA'
Phragmodus →
← Plectodina
CHAMPLAINIAN SERIES
CINCINNATIAN SERIES
Kirkfieldian STAGE
Shermanian STAGE
Edenian STAGE
Maysvillian STAGE
Richmondian STAGE
Lexington Formation
Kope Formation
Dillsboro Formation
S
W
0
50
100%
SHALE % →
0
50
100%
66KE
MAYSVILLIAN STAGE
EDENIAN STAGE


Log AA'
Relative Abundance of Log AA'
Phragmodus →
← Plectodina
S
W
CINCINNATIAN SERIES
Richmondian STAGE
Maysvillian STAGE
Edenian STAGE
Dillsboro Formation
Kope Formation
CHAMPLAINIAN SERIES
Kirkfieldian STAGE
Shermanian STAGE
Lexington Formation
MAYSVILLIAN STAGE
EDENIAN STAGE
0
100
66KB
0
50
100%
SHALE % →
0
50
100%

Ohio State University Form 679 A



Multielement species in Table 1.

1. Phragmodus undatus *
2. Plectodina furcata *
3. Oulodus oregonia velicuspis
4. Drepanodus suberectus
5. Amorphagnathus sp.? **
6. Ozarkodina polita
7. Panderodus panderi
8. Belodina compressa
9. Icriodella superba **

* Indigenous fauna
** European fauna

TABLE 1

Sample	Species 1	2	3	4	5	6	7	8	9	Total
70ZA-23	158	125	68	12	0	36	0	0	0	399
-32	10	14	2	3	0	5	0	0	0	34
-37	61	61	19	3	0	8	0	0	0	152
-43	147	138	26	18	0	5	0	0	0	334
-49	45	21	14	3	0	2	0	0	0	85
-58	17	2	12	1	0	3	0	0	0	35
-63	16	12	10	9	0	0	0	0	0	47
-74	34	10	16	2	0	1	0	0	0	63
-79	65	15	12	6	0	0	1	0	0	99
-84	41	52	10	8	0	0	0	0	0	111
-89	22	24	5	7	0	1	2	0	0	61
-94	13	23	6	6	0	0	1	0	0	49
-100	45	25	18	5	0	0	2	0	0	95
-104	78	44	18	7	0	0	0	0	0	147
-110	26	16	38	7	0	0	0	0	0	87
-115	35	25	15	4	0	0	0	0	0	79
-120	24	38	1	13	0	0	0	0	0	76
-126	12	8	5	2	0	0	0	0	0	27
-129	50	62	46	10	0	0	0	0	0	168
-134	77	141	18	33	0	0	5	0	0	274
-138	372	692	17	46	6	0	5	0	0	1138
-146	15	23	7	2	1	0	0	0	0	48
-150	26	34	31	5	0	0	1	0	0	97
-155	16	54	77	8	0	0	0	0	0	155
-160	8	30	16	6	1	0	1	0	0	62
-165	35	59	52	22	0	0	0	1	0	169
-169	19	37	23	11	1	0	0	0	0	91
-172	27	44	51	4	0	0	0	0	2	128
-176	13	14	19	2	0	0	1	0	0	49
-184	115	45	12	2	0	0	0	0	1	175
-187	146	107	12	17	2	0	0	1	0	285
Totals=	1782	2006	692	287	11	61	19	2	3	4863

References Cited

1. Bergström, S.M.; and Sweet, W.C.; Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana: American Paleonto.Bull.,Vol.50, No.229, pp. 269-441, 1966.

2. Dow, V.E.; Magnetic Separation of Conodonts; J. Paleontol, vol. 34, pp. 738-734, 1960.

3. Ford, J.P.; Cincinnatian Geology in Southwest Hamilton County, Ohio; American ASS. Petrol. Geol. Bull., Vol. 51, pp. 918-936, 1967.

4. Kohut, J.J. and Sweet, W.C.; The American Upper Ordovician Standard. X . Upper Maysville and Richmond conodonts from the Cincinnati Region of Ohio Indiana, and Kentucky: J. Paleontol., Vol. 42, pp. 1456-1477, 1968.

5. LIndström, M. Conodonts, Elsevier Publishing Company; Amsterdam, London, New York, 1964.

6. Pulse, R.R., and Sweet, W.C., The American Upper Ordovician Standard III Conodonts from the Fairview and McMillan Formations of Ohio, Kentucky, and Indiana; J. Paleontol., Vol. 34, pp. 239-264,1960.

7. Scotford, D.M.; Petrology of the Cincinnatian Series Shales and Environmental implications: Geol. Soc. Amer. Bull., Vol. 76, pp. 193-222, 1965.

8. Seddon, G., and Sweet,W.C., An Ecologic Model for Conodonts. J. Paleontol., Vol. 45 (in press) 1971.

9. Sweet, W.C., and Bergström, S,M., The American Upper Ordovician Standard XIII A Revised Time-Stratigraphic Classification of North American Upper Middle and Upper Ordovician Rocks,; Geol. Soc. Amer. Bull., Vol. 82, pp. 613-628, 1971.

10. Sweet, W.C.; Turco, C.A.; Warner, E.; and Wilkie, L.C.; The American Upper Ordovician Standard.I. Eden Conodonts from the Cincinnati Region of Ohio and Kentucky; J. Paleontol., Vol 33, pp.1029-1068, 1959.

11. Sweet, W.C.; Bergström, S.M., and Rust, C.C.; Relative Abundance analysis: an aid to Oredovician conodont biostratigraphy in the Cincinnti Region of Ohio (abstr.); Geol. Soc. Amer., Spec. Pap. 82, p. 203, 1965.

12. Weiss, M.P.: Edwards, W.R.; Norman, C.E. and Sharp, E.R., The American Upper Ordovician Standard. VII. Stratigraphy and petrology of the Cynthiana and Eden Formations of the Ohio Valley; Geo. Soc. Amer., Spec. Pap. 81, p.76, 1965.

13. Weiss, M.P., and Norman, C. E., The American Upper Ordovician Standard. IV Classification of the limestones of the type Cincinnatian; J. Sedment. Petrol., Vol. 30, pp. 283-296, 1960.

14. Weiss, M.P. and Sweet, W.C. Kope Formation (Upper Ordovician) Ohio and Kentucky; Science, Vol. 145, No. 3638, pp. 1269-1302, 1964.